What is claimed is:

	1	1.	A projection optical system capable of forming an image of an object, comprising,
	2		objectwise to imagewise, along an optical axis:
	3		a) a first lens group having positive refractive power;
	4		b) a second lens group having negative refractive power;
	5		c) a third lens group having positive refractive power;
	6		d) a fourth lens group having negative refractive power and a first aspherical
	7		surface;
	8		e) a fifth lens group having positive refractive power and an aperture stop;
	9		f) wherein the projection optical system is designed such that paraxial rays
	10		traveling parallel to the optical axis imagewise to objectwise intersect the
	11		optical axis at a location Q between said fourth lens group and said fifth lens
74	12		group;
W.	13		g) at least one of said fourth and fifth lens groups includes a second aspherical
	14		surface arranged between said first aspherical and said aperture stop;
±	15		h) said fifth lens group includes a hird aspherical surface arranged imagewise of
jul:	16		said aperture stop; and
	17		i) wherein the following condition is satisfied:
	18		
	19		$0.01 < d_Q/\{L \times (1 - NA)\} < 0.4$ (1)
	20		
	21		wherein the image and the object are separated by a distance L, said location Q
	22		and said aperture stop are separated by a distance do, and NA is an imagewise
	23		numerical aperture of the projection optical system.
	1	2.	A projection optical system according to claim 1, wherein said aperture stop has a
	2		variable size and is located imagewise of said location Q such that vignetting is
	3		minimized when said variable size is changed.
			1

4

1	3.	A projection optical system according to claim 1, wherein:
2		a) said first aspherical surface is concave and includes refractive power at a
3		paraxial region and refractive power at a periphery, wherein said refractive
4		power at said periphery is weaker than said refractive power at said paraxial
5		region;
6		b) said second aspherical surface includes refractive power at a paraxial region
7		and refractive power at a periphery, and is one of:
8		i) a convex surface, with said refractive power at said periphery
9		weaker than said refractive power at said paraxial region; and
10		ii) a concave surface, with said refractive power at said periphery
11		stronger than said refractive power at said paraxial region; and
12		c) said third aspherical surface includes refractive power at a paraxial region, and
13		refractive power at a periphery, and is one of:
14		i) a convex surface, with said refractive power at said periphery
15		weaker than said refractive power at said paraxial region; and
16		ii) a concave surface, with said refractive power at said periphery
17		stronger than said refractive power at said paraxial region.
1	4.	A projection optical system according to claim 1, wherein said first lens group has at
2		least one aspherical surface.
1	5.	A projection optical system according to claim 1, wherein said second lens group has
2		at least one aspherical surface.
1	6.	A projection optical system according to claim 1, wherein said third lens group has at
2		least one aspherical surface.
1	7.	A projection optical system according to claim 1, satisfying the following conditions:
2		

(2)

(3)

0.05 < f1/L < 0.5

0.02 < -f2/L < 0.2

5	0	.04 < \ 3/L < 0.4	!	(4)
6	0	.03 < -ru/L < 0.	3	(5)
7	0	.04 < f5/L < 0.4	•	(6)
8				
9	where	ein fl through	5 are focal lengths of said first through fifth lens group	ps,
10	respe	ctively.		
1	8. A pro	jection optical	system capable of forming an image of an object, com	prising,
2	objec	twise to image	wise, along an optical axis:	
3	a)	a first lens gr	oup having positive refractive power;	
4	b)	a second lens	group having negative refractive power;	
5	c)	a third lens g	roup having positive refractive power;	
6	d)	a fourth lens	group having negative refractive power and a first asp	herical
7		concave surfa	ace with refractive power at a paraxial region and refra	ctive
8		power at a pe	riphery, wherein said refractive power at said peripher	y is weaker
9	-	than said refr	active power at said paraxial region;	
10	e)	a second aspl	nerical surface arrange imagewise of said first aspher	ical surface
11		and having re	efractive power at a paraxial region and refractive pow	er at a
12		periphery, an	d being one of:	
13		i)	a convex surface, with said refractive power at said I	periphery
14			weaker than said refractive power at said paraxial re	gion; and
15		ii)	a concave surface, with said refractive power at said	periphery
16			stronger than said refractive power at paraxial region	ı;
17	f)	a fifth lens gr	oup having positive refractive power, an aperture stop	, and a
18		third aspheric	cal surface arranged imagewise of said aperture stop, w	herein said
19		third aspheric	cal surface includes a paraxial region, a periphery and	refractive
20	•	power and is	one of:	
21		i)	a convex surface, with said refractive power at said p	periphery
22			weaker than said refractive power at said paraxial re	gion; and
23		ii)	a concave surface, with said refractive power at said	periphery
24			stronger than said refractive power at paraxial region	ı; and

- wherein the projection optical system is designed such that paraxial rays traveling parallel to the optical axis imagewise to objectwise intersect the optical axis at a location Q between said fourth lens group and said fifth lens group.
- 1 9. A projection optical system according to claim 8, wherein said first lens group has at least one aspherical surface.
- 1 10. A projection optical system according to claim 8, wherein said second lens group has at least one aspherical surface.
- 1 11. A projection optical system according to claim 8, wherein said third lens group has a least one aspherical surface.
- 1 12. A projection optical system according to claim 8, satisfying the following conditions:

- 3 0.05 < f1/L < 0.5 (2)
- 4 0.02 < -f2/L < 0.2 (3)
- 5 0.04 < f3/L < 0.4 (4)
- 6 0.03 < -f4/L < 0.3 (5)
- 7 0.04 < f5/L < 0.4 (6)

8

- wherein f1 through f5 are focal lengths of said first through fifth lens groups, respectively.
- 1 13. An exposure apparatus for imaging a pattern present on a reticle onto a photosensitive workpiece, comprising:
- a) a first stage for supporting the reticle;
- 4 b) an illumination optical system adjacent said first stage for illuminating the reticle;
- 6 c) a second stage for supporting a workpiece; and

7	d)	a proje	ction optical system arranged between said first stage and said secon	nd
8		stage,	said projection optical system comprising in order from said first to	said
9		second	l stage:	
10		i)	a first lens group having positive refractive power;	
11		ii)	a second lens group having negative refractive power;	
12		iii)	a third lens group having positive refractive power;	
13		iv)	a fourth lens group having negative refractive power and a first	
14			aspherical surface;	
15		v)	a fifth lens group having positive refractive power and an aperture	
16			stop;	
17		vi)	wherein the projection optical system is designed such that paraxial	l
18			rays traveling parallel to the optical axis imagewise to objectwise	
19			intersect the optical axis at a location Q between said fourth lens greater	oup
20			and said fifth lens group;	
21		vii)	wherein at least one of said fourth and fifth lens groups includes a	
22			second aspherical surface arranged between said first aspherical	
23			surface in said fourth lens group and said aperture stop;	
24		viii)	wherein said fifth lens group includes a third aspherical surface	
25			arranged imagewise said aperture stop; and	
26		ix)	wherein the following condition is satisfied:	
27			· \frac{\cdot}{\cdot}	
28			$0.01 < d_Q/\{L \times (1 - NA)\} < 0.4$	(1)
29		•		
30			wherein said image and said object are separated by a distance L, sa	aid
31			position Q and said aperture stop are separated by a distance do, and	d
32			NA is an imagewise numerical aperture of the projection optical	
33			system.	

14. An exposure apparatus according to claim 13, wherein said reticle stage and said workpiece stage are moveable along a scanning direction, and said projection optical system includes an exposure field having a first dimension orthogonal to said

•							
	4		scanning direction and a second dimension along said scanning direction, wherein				
	5		said first dimension is greater than said second dimension.				
	1	15.	An exposure apparatus according to claim 14, wherein said first dimension is at least				
	2		25 mm.				
	1	16.	A method of patterning a photosensitive workpiece with a pattern present on a reticle,				
	2		the method comprising the steps of:				
	3		a) illuminating the reticle;				
λ.	4		b) projecting light from said reticle with the projection optical system as set forth				
Wy/	5		in claim k; and				
" H V	6		c) exposing said photosensitive workpiece over an exposure field.				
Company							
had been to meet some than the first	1	17.	A device manufacturing method comprising the steps of:				
2 TOP	2		a) coating a photosensitive material onto a substrate;				
	3		b) projecting onto said substrate the image of a pattern of reticle through the				
	4		projection optical system set forth in claim 1; and				
	5		c) developing said photosensitive material on said substrate, thereby forming a				
	6	ŕ	photoresist pattern.				
pri terring.	1	18.	A method according to claim 17, further comprising the step, after said step c), of				
	2		forming a pattern in said substrate cased on said photoresist pattern.				
	1	19.	A projection optical system capable of forming an image of an object, comprising,				
	2		objectwise to imagewise along an optical axis:				
,	3		a) a first lens group having positive refractive power and a plurality of lenses				
	4		including a negative lens;				
	5		b) a second lens group having negative refractive power and a plurality of				
	6		negative lenses;				
	7		c) a third lens group having positive refractive power and a plurality of positive				
	8		lenses;				

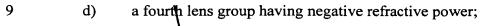
5

6

7

8 9

4



- 10 e) a fifth lens group having positive refractive power and a plurality of lenses 11 including a negative lens; and
- 12 f) an image vise maximum numerical aperture NA_{MAX} of at least 0.8.
- 1 20. A projection optical system according to claim 19, further including an aperture stop located in said fifth lens group.
- 1 21. A projection optical system according to claim 20, further satisfying the following condition:

4
$$0.01 < d_Q/\{L \times (1 - NA)\} < 0.4$$
 (1)

- wherein said image and said object are separated by a distance L, Q is a position located a distance d_Q from said aperture stop wherein paraxial rays traveling parallel to the optical axis imagewise to objectwise intersect the optical axis, and wherein NA is an imagewise numerical aperture of the projection optical system.
- 1 22. A projection optical system according to claim 20, further including an exposure field having a dimension of at least 25 mm.
- 1 23. A projection optical system according to claim 20, wherein the number of lenses 2 objectwise of said aperture stop is at least six, and the number of lenses imagewise of 3 said aperture stop is at least four.
- 1 24. A projection optical system according to claim 20, wherein said aperture stop has a
 2 variable size such that the projection optical system has a numerical aperture NA
 3 satisfying the relation:

 $0.6 \times NA_{MAX} \leq NA \leq NA_{MAX}.$





- 1 25. A projection optical system according to claim 20, wherein the optical axis is 2 unfolded.
- 1 26. A projection optical system having specifications and characteristics as set forth in 2 Tables 1A-1C.
- 27. A projection optical system having specifications and characteristics as set forth in 1 2 Tables 2A-2C.
- A projection optical system having specifications and characteristics as set forth in 1 28. 2 Tables 3A-3C.
- 1 29. A projection optical system having specifications and characteristics as set forth in 2 Tables 4A-4C.
- 30. A projection optical system according to claim 8, satisfying the following conditions: 1

8

3
$$0.05 < f1/L < 0.5$$
 (2)

- 0.02 < -f2/L < 0.24 (3)
- 0.04 < f3/L < 0.45 (4)
- 6 0.03 < -f4/L < 0.3(5)
- 0.04 < f5/L < 0.47 (6)

9 wherein f1 through f5 are focal lengths of said first through fifth lens groups, respectively. 10



- A method of patterning a photosensitive workpiece over an exposure field with a 31. 1 pattern present on a reticle, the method comprising the steps of: 2
- 3 a) illuminating the reticle with light;
- projecting the light from the reticle with the projection optical system as set 4 b) 5 forth in claim 8; and

	6		c)	exposing the photosensitive workpiece over the exposure field.
	1	32.	A pro	jection optical system according to claim 1, wherein:
	2		(a)	said first aspherical surface is concave and includes refractive power at a
	3			paraxial region and refractive power at a periphery, wherein said refractive
	4			power at said periphery is weaker than said refractive power at said paraxial
مار	5			region;
yx.	6		(b)	said second aspherical surface including refractive power at a paraxial region,
N _{IM}	7			and refractive power at a periphery, wherein said refractive power at said
	8			periphery is more negative than said refractive power at said paraxial region;
	9			and
	10		(c)	said third aspherical surface including refractive power at a paraxial region,
	11			and refractive power at a periphery, wherein said refractive power at said
	12			periphery is more negative than said refractive power at paraxial region.
				
_ 566				
	1	33.	An ex	posure apparatus for imaging a pattern present on a reticle onto a photosensitive
the state of the s	1 2	33.		posure apparatus for imaging a pattern present on a reticle onto a photosensitive piece, comprising:
a		33.		. (
a	2	33.	workp	piece, comprising:
a	2 3	33.	workp	piece, comprising: a first stage for supporting the reticle;
2	2 3 4	33.	workp	oiece, comprising: a first stage for supporting the reticle; an illumination optical system adjacent said first stage for illuminating the
a	2 3 4 5	33.	workp (a) (b)	oiece, comprising: a first stage for supporting the reticle; an illumination optical system adjacent said first stage for illuminating the reticle;
a	2 3 4 5 6	33.	workp (a) (b) (c)	oiece, comprising: a first stage for supporting the reticle; an illumination optical system adjacent said first stage for illuminating the reticle; a second stage for supporting the workpiece; and
a	2 3 4 5 6 7	33.	workp (a) (b) (c)	oiece, comprising: a first stage for supporting the reticle; an illumination optical system adjacent said first stage for illuminating the reticle; a second stage for supporting the workpiece; and a projection optical system arranged between said first stage and said second
a	2 3 4 5 6 7 8	33.	workp (a) (b) (c)	oiece, comprising: a first stage for supporting the reticle; an illumination optical system adjacent said first stage for illuminating the reticle; a second stage for supporting the workpiece; and a projection optical system arranged between said first stage and said second stage, said projection optical system comprising in order from said first to said
a	2 3 4 5 6 7 8	33.	workp (a) (b) (c)	biece, comprising: a first stage for supporting the reticle; an illumination optical system adjacent said first stage for illuminating the reticle; a second stage for supporting the workpiece; and a projection optical system arranged between said first stage and said second stage, said projection optical system comprising in order from said first to said second stage:
a	2 3 4 5 6 7 8 9	33.	workp (a) (b) (c)	a first stage for supporting the reticle; an illumination optical system adjacent said first stage for illuminating the reticle; a second stage for supporting the workpiece; and a projection optical system arranged between said first stage and said second stage, said projection optical system comprising in order from said first to said second stage: (i) first lens group having positive refractive power;
a	2 3 4 5 6 7 8 9 10	33.	workp (a) (b) (c)	biece, comprising: a first stage for supporting the reticle; an illumination optical system adjacent said first stage for illuminating the reticle; a second stage for supporting the workpiece; and a projection optical system arranged between said first stage and said second stage, said projection optical system comprising in order from said first to said second stage: (i) first lens group having positive refractive power; (ii) a second lens group having negative refractive power;
a	2 3 4 5 6 7 8 9 10 11 12	33.	workp (a) (b) (c)	biece, comprising: a first stage for supporting the reticle; an illumination optical system adjacent said first stage for illuminating the reticle; a second stage for supporting the workpiece; and a projection optical system arranged between said first stage and said second stage, said projection optical system comprising in order from said first to said second stage: (i) first lens group having positive refractive power; (ii) a second lens group having negative refractive power; (iii) a third lens group having positive refractive power;
a	2 3 4 5 6 7 8 9 10 11 12	33.	workp (a) (b) (c)	a first stage for supporting the reticle; an illumination optical system adjacent said first stage for illuminating the reticle; a second stage for supporting the workpiece; and a projection optical system arranged between said first stage and said second stage, said projection optical system comprising in order from said first to said second stage: (i) first lens group having positive refractive power; (ii) a second lens group having negative refractive power; (iii) a third lens group having positive refractive power; (iv) a fourth lens group having negative refractive power and a first

1 /		(٧)	a second aspherical surface arranged imagewise of said first aspherical
18			surface and having a paraxial region, a periphery and refractive power,
19			said first aspherical surface being one of:
20			(1) a convex surface, with said refractive power at said periphery
21			weaker than said refractive power at said paraxial region; and
22			(2) a concave surface, with said refractive power at said periphery
23			stronger than said refractive power at said paraxial region;
24		(vi)	a fifth lens group having positive refractive power, an aperture stop,
25			and a third aspherical surface with a paraxial region, a periphery and
26			refractive power, said third aspherical surface being one of:
27			(1) a convex surface, with said refractive power at said periphery
28			weaker than said refractive power at said paraxial region; and
29			(2) a concave surface, with said refractive power at said periphery
30			stronger than said refractive power at said paraxial region; and
31		(vii)	wherein the projection optical system is designed such that paraxial
32			rays traveling parallel to the optical axis imagewise to objectwise
33			intersect the optical axis at a location Q between said fourth lens group
34			and said fifth lens group.
	•		
1	34.	An exposure	apparatus according to claim 33, wherein said first stage and said second
2		stage are mov	rable along a scanning direction, and said projection optical system
3		includes an ex	sposure field having a first dimension orthogonal to said scanning
4		direction, and	a second dimension along said scanning direction, wherein said first
5		dimension is	greater than second dimension.
1	35.	An exposure	apparatus for projecting a image of a pattern present on a reticle onto a
2		photosensitiv	e workpiece, comprising:
3		(a) a first	stage designed so as to be movable along a scanning direction and to
4		suppo	rt the reticle;
5		(b) an illu	minating optical system adjacent said first stage arranged so as to
6		illumi	nating the reticle with light;

	7		(c) a second stage designed so as to be movable along at least said scanning
	8		direction, for supporting the photosensitive workpiece;
	9		(d) a projection optical system, arranged between said first stage and said second
	10		stage, having a plurality of lenses and an aperture stop, said plurality of lenses
	11		and said aperture stop designed such that said light from said reticle is capable
	12		of being guided to an exposure field on said substrate with an imagewise
	13		maximum numerical aperture of at least 0.8; and
	14		(e) wherein said exposure field has a first dimension orthogonal to said scanning
	15		direction, and a second dimension along said scanning direction, wherein said
	16		first dimension is greater than and second dimension, and wherein said first
	17		dimension is at least 15mm.
	1	36.	A exposure apparatus according to claim 35, wherein said exposure field has a slit
t.j	2		shape, with said first dimension of said slit shape being at least 25mm.
77 i			
	1	37.	A exposure apparatus according to claim 34, wherein at least one of said plurality of
T	2		lenses includes an aspherical surface.
ini.			
	1	38.	A method of pattering a photosensitive workpiece with a pattern present on a reticle,
	2		the method comprising the steps of:
. Va	3		(a) illuminating the reticle with light from said illuminating optical system of said
N.Y	4		exposure apparatus of claim 35;
1,	` 5		(b) projecting the light from the reticle with the projection optical system of said
	6		exposure apparatus of claim 35; and
	7		(c) exposing said photosensitive workpiece over said exposure field.

